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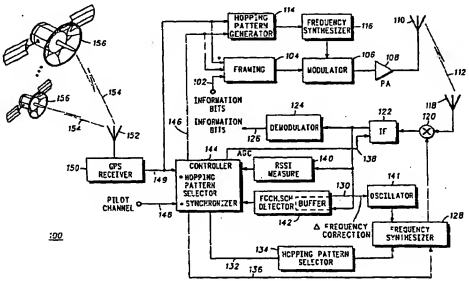

(57) Abstract

A communication unit (200) for use in a communication system is provided which includes a hopping mechanism (114, 144) which hops communication frames over a plurality of carrier frequencies according to a predetermined hopping pattern. At least one of the communication frames preferably includes a synchronization channel time slot having data bits from which the predetermined hopping pattern may be derived. In addition, a communication unit (100) is provided which includes a signal acquisition mechanism (142) for initially acquiring a predetermined hopping pattern that specifies the sequence over which hop frames are hopped over a plurality of carrier frequencies. Also, this communication unit (100) includes a hopping mechanism (134, 144) for hopping receiving frequency according to the predetermined hopping pattern such that a control channel may be detected. In an alternative embodiment, either communication unit may derive the predetermined hopping pattern from detected global position satellite information (149).

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METHOD AND APPARATUS FOR OPERATING WITH A HOPPING CONTROL CHANNEL IN A COMMUNICATION SYSTEM

Related Invention

The present invention is related to U.S. Patent Application Serial Number 07/955,793 filed on October 2, 1992, by Borth et al. which is entitled "Method and Apparatus for Frequency Hopping a Signaling Channel in a Communication System" and was assigned to the assignee of the present invention.

Field of the Invention

The present invention relates to communication systems which employ time division multiple access (TDMA) signals and, more particularly, to a method and apparatus for operating with a hopping control channel in a communication system.

Background of the Invention

In a TDMA communication system, such as the European digital cellular radiotelephone systems which are set forth in the open air interface Global System for Mobile Communications (GSM) standard

(Copies of GSM are available from European Telecommunications Standards Institute, ETSI Secretariat: B.P.152.F-06561 Valbonne Cedex, France) or a derivative thereof such as Digital Cellular System 1800 MegaHertz (DCS1800), there are typically a plurality of radio frequencies employed at each base site. Each frequency is time partitioned into frames, each having several time slots. Each time slot may carry radiotelephone communication between a particular base site and a subscriber unit (i.e., mobile communication unit) located within the coverage area of the particular base site.

In addition, the performance of TDMA communication systems can be improved by introducing a frequency hopping pattern to the signal modulation process. Frequency hopping helps a communication system maintain the integrity of a communication channel by providing frequency diversity. This, in combination with the channel coding and interleaving, mitigates the effects of Rayleigh fading. In addition, frequency hopping is an important counter-measure which reduces a channel's susceptibility to co-channel interference and jamming (which was intended or accidental in nature).

Frequency hopping consists of shifting the carrier frequency of a particular information signal in discrete increments in a pattern dictated by a code sequence or pattern. In particular, the transmitter jumps from frequency to frequency according to a code sequence. Frequency hopping communication systems can be divided into slow frequency hopping (SFH) and fast frequency hopping (FFH) communication systems. In SFH communication systems, several data symbols, representing a sequence of data bits (e.g., an information signal), modulate the carrier wave within a single hop. Whereas, in FFH communication systems, the carrier wave hops several times per data symbol.

In an SFH communication system, multiple communication channels are accommodated by the assignment of portions of a broad frequency band and/or time slot to each particular channel. For example, communication between two communication units in a particular communication channel is accomplished by using a frequency synthesizer to generate a carrier wave in a particular portion of a predetermined broad frequency band for a brief period of time. The frequency synthesizer uses an input hopping code to determine the

particular frequency from within the set of frequencies in the broad frequency band which the carrier wave will be transmitted on. Hopping codes are input to the frequency synthesizer by a hopping code generator. The hopping code generator is periodically clocked or stepped through different transitions which cause different or shifted hopping codes to be output to the frequency synthesizer. Therefore, as the hopping code generator is periodically clocked, then so too is the carrier wave frequency hopped or reassigned to different portions of the broad frequency band.

Multiple communication channels are allocated by using a plurality of hopping codes to assign portions of the frequency band to different channels during the same time period. As a result, transmitted signals are in the same broad frequency band of the communication channel, but within unique portions of the broad frequency band assigned by the unique hopping codes. These unique hopping codes preferably are orthogonal to one another for each cell or communication service region such that the cross-correlation between the hopping codes is zero.

In the GSM standard, a scheme for frequency hopping traffic channels in time slots is described. If this scheme is implemented significant performance improvements can be obtained. However, in the GSM system, the control channel is not designed to hop, because the system was optimized for a simplified acquisition by subscriber units to the communication system. Therefore, in order to provide simplified access, the control channel is transmitted at a fixed frequency so that it acts like a beacon for subscriber units to use in acquiring the communication system (e.g., the control channel beacon is used to frequency tune and time align the subscriber unit to the communication system). However, this makes the control channel vulnerable to jamming and Rayleigh fading. Therefore, a need exists for a scheme to accommodate frequency hopping of the control channel, while still allowing the mobile units to acquire the communication system.

Brief Description of the Drawings

FIG. **1** is a block diagram showing a preferred embodiment subscriber communication unit for use in a communication system in accordance with the present invention.

FIG. **2** is a block diagram showing a preferred embodiment base site communication unit for use in a communication system in accordance with the present invention.

FIG. **3** is a block diagram showing a preferred embodiment detector for use in either communication unit shown in FIGs. **1** or **2** in accordance with the present invention.

FIGs. **4** and **5** are diagrams showing two different preferred embodiment frame structures for use in a communication system having a hopped control channel in accordance with the present invention.

FIGs. **6, 7,** and **8** are flowcharts showing three different preferred embodiment techniques for obtaining a hopping pattern in accordance with the present invention.

FIGs. **9** and **10** are flowcharts showing two different preferred embodiment techniques for detecting a synchronization channel time slot in accordance with the present invention.

Detailed Description

In current GSM systems, which are non-hopping control channel systems, there are two types of control information which must be acquired by the subscriber unit before the subscriber can access a traffic channel. The first type of information is frequency correction information. This is provided in a frequency correction channel (FCCH). The FCCH is a pure sine wave inserted periodically in a time slot in certain frames which is used by the communication unit to correct its local oscillator to within a range of the base station transmitter's frequency. In addition, this frequency detection will provide a coarse time alignment to the time slot structure. This information is provided on a carrier used by the system, where the carrier is time partitioned into frames and each frame is divided into several time slots.

The second type of information needed by the subscriber unit in order to acquire the communication system is the synchronization

information. This is provided in a synchronization channel (SCH). The SCH is a time slot inserted periodically in certain frames. In the SCH time slot, accurate timing information is determined by use of a specific synchronization word. The location of the correlation peak for a training sequence within the synchronization word in the SCH may be used to yield timing for the communication system to within a symbol period.

Because of the amount of information to be transferred by the FCCH and SCH, they are typically not provided in the same time slot. Further, due to the complexity of the signal processing necessary for detection of the FCCH and SCH, they are typically not provided in the same frame. In order to utilize the least amount of spectrum (i.e., channel usage) for the control channel (leaving as much as possible for the traffic channels) both the FCCH and SCH are periodically sent different frame, but in the same time slot (e.g., time slot 0). To accomplish this, the FCCH is sent in one frame (F_N) and the SCH is sent in another frame (F_{N+1}). Several frames may not have either the FCCH or the SCH so that more control channels may be provided in the communication system. In GSM, the frames are grouped into frame co-sets, as illustrated in FIG. 4. This frame co-set consists of ten frames. In this embodiment, the FCCH and the SCH are transmitted in only one frame of the co-set.

Once this FCCH and SCH information have been obtained by the communication unit, it can transfer and receive messages over the other control channels and receive its traffic channel assignment. These other control channels include: a Slow Dedicated Control Channel (SDCCH), Paging Channel (PCH), Random Access Channel (RACCH), and/or Access Grant Channel (AGCH) may be used by the communication system. Some of these control channels are only used with the uplink (i.e., subscriber-to-base site communication unit) or downlink (i.e., base site-to-subscriber communication unit) communications.

In practice, a communication unit will scan several frequencies and measure a quality factor, such as signal strength, at each frequency. Subsequently, the communication unit prioritizes the frequencies from highest to lowest signal strength (i.e., the closest base site communication unit will likely have the highest signal strength). The communication unit will then go to the frequency having the best quality factor and obtain the frequency correction from the FCCH (frame F_N, slot

0) and the synchronization and hopping pattern from the SCH (frame F_{N+1}, slot 0). In the non-hopping system, this takes two frames to accomplish.

As indicated, the above description was for a non-hopping control channel system. However, the GSM standard does allow for frequency hopping; but only for the traffic channels. The control channels remain at fixed frequencies. This is accomplished by making time slot 0 of some frames at certain frequencies the control channel. The information needed by the communication unit to begin hopping the traffic channel is obtained over two consecutive frames having control slots (i.e., FCCH and SCH) as well as a later transmitted frame having a control slot(i.e., a broadcast control channel).

The acquisition process is made more difficult when the control channel is also hopped. This will change the amount of time the communication unit will be required to "camp out" on a single frequency to obtain the necessary control information. In a hopping control channel system which hops on a frame-by-frame basis, the FCCH will be contained in frame F_N at a certain frequency whereas the SCH will be contained in the following frame F_{N+1} at another frequency. An example of this type of process is described in the above identified related invention.

A problem with the above-referenced implementation is that when the subscriber unit is not "a priori" provided with the sequence over which the frequencies are hopped, it does not know which frequency the SCH will be located in after the FCCH is detected. In addition, another problem is when there is a jammer attempting to jam the communication system. It is not desirable to have all communication units "a priori" know the sequence over which the frequencies are hopped. In such a system, the jammer will try to access the frequency being used by the communication unit (e.g., the frequency which carries the SCH and/or FCCH) and put out enough noise at that frequency such that the subscriber communication unit will not be able to recover the transmitted signal.

It is easier for the jammer to try to keep the communication unit from gaining access to the system by jamming the control signals. When jamming a signal, it is very difficult for the jammer to identify the random data bits transmitted in the traffic channels. While it is a little easier to try

to identify the synchronization word in the SCH, this is only a small part of that time slot and it is likewise difficult to identify in time to jam. This leaves the FCCH which, as stated above is a pure sine wave time slot. The jammer can detect this time slot; lock to that frequency; and begin jamming the signal. This can be done in time to jam the SCH and prevent the communication unit from obtaining the hopping pattern. This, in effect, blocks the communication unit from the system.

The present invention provides a system design as well as the associated communication units (base and subscriber) for implementing the system design. This design addresses several of the issues noted above including not "a priori" knowing the frequency hopping sequence by the subscriber unit and jamming.

In accordance with the present invention, two alternative hopping control channel solutions are proposed. For these solutions, the SCH, in addition to the synchronization word, will also provide the communication unit with the hopping pattern, or spreading code. This code may be the specific hopping pattern or can be an identifier of the hopping pattern. The identifier would then be used by the communication unit to generate the hopping pattern. In the first solution, as shown in FIG. 4, the SCH is placed in a time slot before the FCCH. Since the jammer will be looking for the FCCH, the design in FIG. 4 will enable the communication unit to receive the SCH before the jamming starts. In addition, enough of the FCCH signal can be obtained before jamming begins to enable the communication unit to adjust its frequency accordingly. In this solution, the SCH has been received and is safely stored in a receiver buffer when the FCCH is sent. As such, an interference signal (e.g., a jamming signal) would be ineffective. Since the jammer would not know where to find the next frequency in the hopping sequence, the communications unit would be able to acquire the traffic channel and conduct the communication.

To implement this first solution, a buffer is required to store the SCH. In addition, the frequency reference source (i.e., the local oscillator) must be corrected accurately enough during the FCCH detection so that the samples within the stored SCH can be frequency corrected. For example, if the buffered samples of the SCH are r_n, then for an assumed frequency error the sample (r_n) must be corrected as frequency corrected sample $\tilde{r}_n = r_n e^{-j2\pi\Delta f n T_s}$ where r_n is the original

sample stored in the buffer, $\tilde{r}_n$ is the frequency corrected sample, Δf is the frequency correction term, and T_S is the sampling interval.

In the second hopping control channel solution, as shown in FIG. 5, the SCH and FCCH are in the same frame, but separated by several intermediate slots. The advantage of this solution is that if the GSM receiver is already capable of receiving and processing two slots within seven slots (typically it must receive two slots within at least eight slots) then no additional hardware redesign of the communication unit is needed. Unlike the first solution, only the same one slot buffer, used in known GSM receivers is used in the second solution. Only software, which implements slow frequency hopping (i.e., varying the output of the frequency synthesizer on a frame by frame basis) is needed. This second solution, like the first solution, is still useful in reducing or eliminating the effects of some types of interference in the acquisition of a system. Besides jamming, these types of interference include: co-channel interference, co-site interference, sun spots, and any other type of intermittent interference (e.g., point-to-point communications).

In accordance with the second hopping control channel solution (as shown in FIG. 5), the FCCH is transmitted in the first time slot of a frame (e.g., frame F_N in slot 0) and the SCH is transmitted in the eighth slot of the same frame (e.g., frame F_N in slot 7). A communication unit which operates according to this second solution will operate in substantially the same manner as was described above in reference to the first solution, except that a two slot buffering mechanism (i.e., memory device) is not needed. The communication unit can detect the FCCH from data samples of the first slot of a frame, calculate the frequency correction term, adjust the local oscillator according to the frequency correction term, purge the buffer which stores these data samples, and then ready itself to detect the SCH from data samples of the eighth slot of the same frame. This would function for most types of interference, except deliberate jamming.

It should be noted that the location of the FCCH can be used as information which indicates the location of the SCH. For example, if in accordance with the first hopping control channel solution the FCCH is received in the second time slot of a frame, then the SCH is located in an earlier transmitted time slot within the same frame. Also, if in accordance with the second hopping control channel solution the FCCH

is received in the first time slot of a frame, then the SCH is located in a later transmitted time slot within the same frame

Three different preferred embodiment methods for obtaining a hopping pattern in accordance with the present invention are illustrated in FIGs. **6**, **7**, and **8**. In each method, data samples (i.e., bits) are received **402** from the SCH. Subsequently, the predetermined hopping pattern is selected according to one of three different methods. The first method consists of using **412** the synchronization channel time slot data bits to address a hopping pattern lookup table and then retrieve **414** a particular addressed hopping pattern from the lookup table. The second method consists of deriving **420** the carrier frequency of the next frame within the predetermined hopping pattern and then retrieving **422** the hopping pattern from a subsequent frame or frames. Finally, the third method consists of deriving **404** the hopping pattern as a function of the synchronization channel time slot data bits directly (e.g., the next frames are pointed to by the data bits).

One implementation of the third method is to derive the hopping pattern as a function of a frame number. The time division multiple access frame number may be initially acquired by determining the time division multiple access frame number from the synchronization channel time slot data bits. Alternatively, the time division multiple access frame number may be initially acquired by determining a "reduced" time division multiple access frame number from the synchronization channel time slot data bits. This "reduced" time division multiple access frame number identifies a co-set of time division multiple access frames including a single synchronization channel time slot within a predetermined time division multiple access frame of the time division multiple access frame co-set. Subsequently, the frame number is determined from the determined reduced frame number and the predetermined frame of the frame co-set. Once the time division multiple access frame number is acquired, the predetermined hopping pattern may be determined by using the acquired frame number to retrieve a particular hopping pattern from a lookup table of hopping patterns. Alternatively, the hopping pattern may be determined directly from the acquired time division multiple access frame number.

Referring now to FIG. **2**, a preferred embodiment base site communication unit **200** for use in a slow frequency hopping

communication system in accordance with the present invention is shown. Information bits **102** are input to the transmitting portion of the base site **200**. It will be appreciated by those skilled in the art that the information bits **102** may consist of digitized voice, data, or a combination thereof. The information bits **102** are input to a framing device **104** which divides the incoming information bits **102** into discrete groups which are to be transmitted as a group in individual time slots within a frame structure. The frame structure preferably is derived in part from a synchronization signal **146** coming from the receiving portion of base site **200**.

In an alternative embodiment, another type of synchronization signal **149** may be used by base site **200**. Synchronization signal **149** is generated as a function of global position satellite (GPS) information received over a communication channel **154** from one or more satellites **156** through an antenna **152** by a GPS receiver **150**. GPS receiver **152** preferably acquires the current time of day and/or location of the demodulator as the GPS information from the one or more satellites **156**. It will be appreciated by those skilled in the art that the operation of a GPS receiver **150** is well known in the art.

Either synchronization signal **146** or **149** is used by framing device **104** to synchronize a local oscillator **141** to the SFH communication system. The local oscillator **141** provides a clock signal to framing device **104** which in turn groups the incoming information bits **102** based on the clock signal. These information bits **102** may consist of information to be transmitted over one or more control and traffic channels (e.g., in a base site communication unit several information sources are multiplexed together into frames by the framing device **104** so that each time slot carries information of individual control and traffic channels that each come from several information sources).

In the preferred embodiment, the information bits **102** include control information used by a subscriber communication unit **100** (shown in FIG. **1**) to initially synchronize to the SFH communication system, maintain synchronization, and to obtain system information. This control information consists of at least a frequency correction channel (FCCH) and a synchronization channel (SCH). These two "logical" channels, as shown in FIGs. **4** and **5**, are multiplexed onto a single "physical" channel such that they are transmitted in the same

frequencies and frames. In the preferred embodiment, as shown in FIG. **4**, the SCH is transmitted in slot 0 of a frame and the FCCH is transmitted in slot 1 of the same frame. In an alternative embodiment, as shown in FIG. **5**, the FCCH is transmitted in slot 0 of a frame and the SCH is transmitted in slot 7 of the same frame.

The frames to be transmitted are logically grouped into frame co-sets by framing device **104** such that the FCCH and SCH are transmitted in only one frame of a frame co-set. In one preferred embodiment, a frame co-set consists of ten frames such that the FCCH and SCH are only transmitted approximately once every ten frames (i.e., five times in a 51 frame multiframe). In this system the SCH includes a "reduced" frame number which specifies which co-set (i.e., a co-set number) is being received. Further, the "full" frame number is calculated by a priori knowing that the SCH is transmitted in a particular frame (e.g., the second out of ten frames) within the co-set. Thus, in this example, the frame number is the co-set number plus two frames. It will be appreciated by those skilled in the art that other types of control information may also be inserted into the information bits **102**.

Once the information bits **102** to be transmitted are organized, a hopping pattern generator **114** is used to generate at least one of a plurality of hopping patterns from a group of hopping patterns. Hopping pattern generator **114** is periodically clocked or stepped through different transitions by synchronization signals **146** or **149** to cause different or shifted hopping patterns to be output to a frequency synthesizer **116**.

Frequency synthesizer **116** generates a carrier wave at a particular narrow band of a broad frequency band for a brief period of time. The particular narrow band that frequency synthesizer **116** generates is selected from a plurality of narrow bands as specified by the hopping pattern. As hopping pattern generator **114** is periodically clocked, then so too is the carrier wave frequency hopped to different portions of the frequency band by frequency synthesizer **116**.

The frequency hopping carrier wave is input to a modulator **106**. Modulator **106** modulates the carrier wave with the framed information bits output by framing device **104**. It will be appreciated by those skilled in the art that modulator **106** may modulate the carrier wave with any one of several modulation techniques such as frequency shift keying

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(FSK), minimum shift keying (MSK), Gaussian minimum shift keying (GMSK), or phase shift keying (PSK) including any derivatives thereof such as binary or quadrature phase shift keying (BPSK or QPSK) without departing from the scope or spirit of the present invention.

A signal ready for transmission over a communication channel **112** (e.g., radio link or wire line) is output by modulator **106**. However, the transmission signal output by modulator **106** may be too weak to transmit over the communication channel **112**. If this is the case, then the transmission signal may be amplified by a power amplifier (PA) **108**, prior to its transmission by antenna **110** over the communication channel **112**.

FIG. 1 shows a receiving portion for the preferred embodiment subscriber communication unit **100** for use in a SFH communication system in accordance with the present invention. A signal is received by antenna **118** over communication channel **112** from a base site communication unit **200**. This received signal is input to a mixer **120** which receives a fixed carrier wave signal from frequency synthesizer **128** and mixes (e.g., multiplied) it with the received signal. Subsequently, a down-converter **122** converts the received signal to an intermediate frequency (IF) which can more easily be manipulated by other receiver components.

This down-converted received signal is then input to a FCCH, SCH detector **142**. In FIG. **3**, a preferred embodiment detector **142** is shown. The down-converted received signal is input to an analog-to-digital (A/D) converter **300** which digitizes the received analog signal into a stream of data samples. The data samples are stored in a buffer **302** which preferably is capable of buffering two time slots worth of data samples. As data is stored, the detector **142** searches for and measures the frequency of an FCCH, which in this example, would be in the second time slot of the frame. This FCCH will provide a coarse time alignment to the time slot structure of the SFH communication system. Once the FCCH is detected, subscriber communication unit **100** will freeze the buffer **302**. The stored data samples in the frozen buffer **302** belonging to an FCCH are used by a frequency error estimator **306** to generate a frequency error correction signal which is input to a multiplier **304**. Such that, if the buffered samples of the SCH are r_n, then for an assumed frequency error, the sample (r_n) must be corrected as

frequency corrected sample $\tilde{r}_n = r_n e^{-j2\pi\Delta f n T_s}$, where $\tilde{r}_n$ is the frequency corrected sample, Δf is the frequency correction term, and T_s is the sampling interval. Multiplier **304** multiplies the error correction signal with the samples belonging to the SCH delayed (i.e., buffered data samples) to generate a frequency corrected stream of data samples.

In addition, the frequency reference source (i.e., the local oscillator **141**) used by the receiving portion of the subscriber unit **100** must be corrected accurately enough so that samples may be decoded by FCCH, SCH detector **142** and/or demodulator **124**. A difference (Δf) frequency correction control line **130** from the frequency error estimator **306** corrects the frequency of the oscillator **141** via a feedback path with the FCCH, SCH detector **142**.

In addition, the FCCH samples are used by controller **144** to estimate the signal gain in order to adjust gain control, with an automatic gain control (AGC) feedback signal **138**, to keep the received signal within the linear operating portion of the communication unit.

Subsequently, since the detector **142** has buffered data samples into a memory device from at least two time slots and it has detected the FCCH in the second time slot, then communication unit **100** knows the SCH is located in the previous time slot (i.e., the first time slot) of the frame and can now decode the previously stored SCH burst. In this SCH, accurate timing information and a specific synchronization word used by the serving base site for all normal control and traffic channel bursts is determined. The location of the correlation peak for the training sequence (synch word) in the SCH yields timing for the communication system to within a symbol period. In addition, one of the data fields in the SCH provides a frame number reference. From this SCH derived information, controller **144** can determine what the hopping pattern is and direct, via control lines **146** and **132**, respectively, the hopping pattern generators **114** and **134** to generate the hopping pattern for the frequency synthesizers **116** and **128** to use, respectively. At this point, the communication unit is synchronized and is capable of communicating within the SFH communication system.

Once the communication unit is synchronized to the SFH communication system, the received signal is input to a mixer **120** which removes the effects of frequency hopping. Mixer **120** receives a carrier wave signal from frequency synthesizer **128** and mixes (e.g.,

multiplied) it with the received signal. The frequency synthesizer **128** receives a hopping pattern from hopping pattern generator **134** which was determined in the synchronization process.

Subsequently, a down-converter **122** converts the received signal to an intermediate frequency (IF) which can more easily be manipulated by other receiver components. The down-converted received signal is then be input to a demodulator **124** which detects information bits **126** in the received signal. It will be appreciated by those skilled in the art that demodulator **124** performs the inverse of modulation operation performed prior to transmission of the signal over communication channel **112**. For example the demodulator **124** may perform a coherent or non-coherent detection of the received signal and/or a maximum likelihood sequence estimate the information bits **126**.

It will be appreciated by those skilled in the art that it may be desirable, after an initial acquisition of the SCH has been accomplished, to have a communication unit **100** in this communication system scan several frequencies by changing the output of the frequency synthesizer **128**. Subsequently, at each frequency, a received signal strength indicator (RSSI) device **140** may be used to measure the signal strength of a received signal present. Subsequently, the communication unit **100** can use a controller **144** to prioritize the channels from highest to lowest signal strength (i.e., the closest base site communication unit will likely have the highest signal strength) so that subsequent communications with the communication system occur with the base site communication unit having the best reception by the subscriber. This is used in both initial registration of the subscriber unit and for handoff/handover purposes.

Also, it will be appreciated by those skilled in the art that the SCH may contain information on more that one hopping pattern and the controller **144** may hop the receiving portion of communication unit **100** according to a first and a second predetermined hopping pattern such that two control channels can be detected and the better control channel based on a comparison of measured signal quality be selected for subsequent use. Signal quality may be determined by bit error rate, relative signal strengths, strengths of correlation peaks, and/or delay spread.

FIG. 1 also shows a transmitting portion for the a preferred embodiment subscriber communication unit **100** for use in a SFH communication system in accordance with the present invention. The transmitting portion operates in a substantially similar manner as the base site **200** transmitting portion described above, except that the subscriber unit **100** does not need to provide FCCH and SCH control channels. Information bits **102** are input to the transmitting portion of the subscriber communication unit **100**. Information bits **102** may consist of digitized voice, data, or a combination thereof. Information bits **102** are input to a framing device **104** which divides the incoming information bits **102** into discrete groups which are to be transmitted as a group in individual time slots within a frame structure. The frame structure preferably is derived in part from a synchronization signal **146** coming from the receiving portion of the subscriber communication unit **146**. This synchronization signal **146** is derived during the initial synchronization process for the receiver and is corrected over time by the receiver circuitry.

In an alternative embodiment, another type of synchronization signal **149** may be used by both the transmitting and receiving portion of the subscriber communication unit **100**. This alternative synchronization signal **149** is generated as a function of global position satellite (GPS) information received over a communication channel **154** from one or more satellites **156** through an antenna **152** by a GPS receiver **150**. GPS receiver **152** acquires the current time of day and/or location of the demodulator as the GPS information from satellite **156**.

Either synchronization signal **146** or **149** is used by framing device **104** to synchronize a local oscillator **141** to the SFH communication system. The local oscillator **141** provides a clock signal to framing device **104** which in turn groups the incoming information bits **102** based on the clock signal.

In addition, either synchronization signal **146** or **149** is used by a hopping pattern generator **114** to generate at least one of a plurality of hopping patterns from a group of predetermined hopping patterns. Hopping pattern generator **114** is periodically clocked or stepped through different transitions by synchronization signal **146** or **149**. This causes different, or shifted, hopping patterns to be output to a frequency synthesizer **116**. The hopping patterns are hopping patterns which are

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provided to an input of frequency synthesizer **116**. Frequency synthesizer **116** generates a carrier wave in a particular narrow band of a predetermined broad frequency band for a brief period of time. Frequency synthesizer **116** uses the input hopping pattern to determine the particular frequency from within a set of frequencies in the broad frequency band at which to generate the carrier wave. As hopping pattern generator **114** is periodically clocked, the carrier wave frequency is hopped to different narrow band portions of the broad frequency band by frequency synthesizer **116**. It will be appreciated by those skilled in the art that subscriber unit **100** may have only one frequency synthesizer and hopping pattern generator which provides carrier waves to both the receiving and transmitting portions of base site **100**.

The frequency hopping carrier wave is input to a modulator **106**. Modulator **106** modulates the carrier wave with the framed (i.e., groups of) information bits output by framing device **106**. A signal ready for transmission over a communication channel **112** is output by modulator **106**. However, the transmission signal output by the modulator **106** may be too weak to transmit over the communication channel **112**. If this is the case, the transmission signal may be amplified by a power amplifier **108** (PA), prior to its transmission by antenna **110**.

Referring now to FIG. **2** a receiving portion for the preferred embodiment base site communication unit **200** is also shown. The receiving portion of the base site **200** operates in a substantially similar manner as described above in reference to the subscriber unit's receiving portion. The base site receiving portion differs in that it does not need to have FCCH and SCH detection circuitry to provide frequency hop synchronization, because the subscriber unit **100** is transmitting an information signal to the base site **200** which is synchronized to the frequency hopping pattern previously provided by the base site **200**.

A signal is received by antenna **118** from over the communication channel **112** from the subscriber unit **100**. This received signal is input to a mixer **120** which removes the effects of any frequency hopping. Mixer **120** receives a carrier wave signal from frequency synthesizer **128** and mixes (e.g., multiplied) it with the received signal. Frequency synthesizer **128** preferably operates in a

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substantially similar manner as frequency synthesizer **116** (i.e., receives a hopping pattern from a hopping pattern generator **134**). It will be appreciated by those skilled in the art that a base site communication unit **200** may have only one frequency synthesizer and hopping pattern generator which provides carrier waves to both the receiving and transmitting portions of the communication unit **200**. Similarly, a subscriber unit **100** may have only one frequency synthesizer and hopping pattern generator.

Once the effects of frequency hopping are removed, a down-converter **122** preferably converts the received signal to an intermediate frequency (IF) which can more easily be manipulated by other receiver components. The down-converted received signal may then be input to a demodulator **124** which detects information bits **126** in the received signal. Demodulator **124** performs the inverse of modulation operation which was performed on the signal prior to its original transmission. For example the demodulator **124** may perform a coherent or non-coherent detection of the received signal and/or may maximum likelihood sequence estimate the information bits **126**.

As shown in elements **500-518** of the flowcharts in FIG. **9**, SCH may be detected by the receiving portion of communication unit **100** or **200** with a preferred embodiment technique for detecting in accordance with the present invention. The technique consists of iteratively and sequentially setting **502** (i.e., adjusting) a local oscillator **141** (shown in FIG. **1**) to a frequency until the synchronization channel time slot is detected **506, 518**. It will be appreciated by those skilled in the art that if the SCH is detected according to this algorithm shown in FIG. **9** that the FCCH will not be needed for acquisition.

In a similar manner, as shown in elements **500-518** of FIG. **10** the preferred embodiment techniques for detecting FCCH and SCH may be augmented by iteratively and sequentially setting **510** (adjusting) a gain of a pre-amplifier within the FCCH, SCH detector **142** until the FCCH and/or SCH time slot is detected **512, 514**. The adjusting of the gain of the pre-amplifier adjusts the sensitivity of the receiver circuit such that distortion (i.e., clipping) is eliminated or reduced without sacrificing sensitivity in detecting the received signal.

If the communication units **100** and **200** operating in the SFH communication system utilize GPS receivers (e.g., receiver **150**), then

absolute timing of all of the communication units can be maintained and the hopping pattern can be determined as a function of the time of day and/or location information within the received GPS information. It will be appreciated by those skilled in the art that a separate non-hopping pilot channel **148** (shown in FIG. **1**) or a public switch telephone network (PSTN) timing signal **148** (shown in FIG. **2**) which provides absolute timing information to all communication units operating in the SFH communication system may be substituted for a GPS receiver.

For example, if a mechanism for obtaining absolute timing was available, then a subscriber communication unit would be able to determine where it was located with regard to the nearest base station. In addition, the time of day could also be determined from the GPS information. The location information is then used to select a base station and identify a hopping sequence for that base site. The time of day is use to determine where, in a day long sequence of a hopping pattern (i.e., a spreading code), to start frequency hopping.

Although the invention has been described and illustrated with a certain degree of particularity, it is understood that the present disclosure of embodiments has been made by way of example only and that numerous changes in the arrangement and combination of parts as well as steps may be resorted to by those skilled in the art without departing from the spirit and scope of the invention as claimed.

Claims

What is claimed is:

1. A communication unit for use in a communication system, the communication unit characterized by hopping means for hopping a plurality of communication frames over a plurality of carrier frequencies according to a predetermined hopping pattern, at least one of the plurality of communication frames comprising a synchronization channel time slot, the synchronization channel time slot comprising data bits from which the predetermined hopping pattern can be derived.

2. A communication unit for use in a communication system, the communication unit characterized by:

(a) signal acquisition means for initially acquiring a predetermined hopping pattern which specifies the sequence over which a plurality of communication frames are hopped over a plurality of carrier frequencies, the signal acquisition means comprising detecting means for detecting a synchronization channel time slot within a communication frame, the synchronization channel time slot comprising data bits from which the predetermined hopping pattern may be derived; and

(b) hopping means, operatively coupled to the signal acquisition means, for hopping a receiving frequency of the signal acquisition means according to the predetermined hopping pattern such that a control channel may be detected.

3. The communication unit of claim 2 wherein:

each of the plurality of communication frames comprises a plurality of time slots, at least one of the plurality of time slots of a particular communication frame comprising the synchronization channel time slot;

another of the plurality of time slots of the particular communication frame comprises a frequency correction channel time slot, the frequency correction channel time slot comprising information for indicating a location of the synchronization channel time slot within the particular communication frame;

the signal acquisition means comprises:

(a) memory means, operatively coupled to the detecting means, for concurrently storing information from a plurality of time slots including the frequency correction channel time slot and the synchronization channel time slot wherein the information from the frequency correction channel time slot indicates that the synchronization channel time slot is located within an earlier transmitted time slot within the particular communication frame; and

(b) determining means, operatively coupled to the memory means, for retrieving synchronization channel time slot information from the stored particular earlier transmitted time slot and determining the predetermined hopping pattern; and

the determining means comprises means for frequency error correcting the stored particular earlier transmitted time slot based on information from the frequency correction channel time slot prior to retrieving synchronization channel time slot information from the stored particular earlier transmitted time slot.

4. The communication unit of claim 2 wherein:

(a) the synchronization channel time slot comprises data bits from which a plurality of predetermined hopping patterns may be derived;

(b) the hopping means comprises:

(i) means for hopping a frequency of a receiver according to a first and a second predetermined hopping pattern such that a first and a second control channel may be detected, respectively; and

(ii) selection means for selecting one of the first and the second predetermined hopping patterns to continue hopping the receiver based on a comparison of a

measured signal quality of the first and the second detected control channel.

5. A communication unit for use in a communication system, the communication unit characterized by:

(a) global position satellite detecting means for detecting global position satellite information;

(b) signal acquisition means, operatively coupled to the global position satellite detecting means, for acquiring a predetermined hopping pattern by utilizing the detected global position satellite information, the predetermined hopping pattern specifying the sequence over which a plurality of communication frames are hopped over a plurality of carrier frequencies; and

(c) hopping means, operatively coupled to the signal acquisition means, for hopping a frequency of a receiver according to the predetermined hopping pattern such that a control channel may be detected.

6. A method for providing a hopping pattern to a communication unit for use in a frequency hopping communication system, comprising:

(a) scanning a particular set of frequencies for a communication frame including a synchronization channel time slot;

(b) detecting the synchronization channel time slot within the communication frame; and

(c) determining a predetermined hopping pattern which specifies the sequence over which a plurality of the communication frames are hopped over a plurality of carrier frequencies from data bits within the synchronization channel time slot.

7. The method of claim 6 wherein the step of determining comprises using the data bits within the synchronization channel time slot to acquire the predetermined hopping pattern according to a step selected from the group consisting of:

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(a) retrieving the predetermined hopping pattern from a lookup table of hopping patterns;

(b) deriving a carrier frequency of a next communication frame within the predetermined hopping pattern; and

(c) deriving the predetermined hopping pattern as a function of the data bits within the synchronization channel time slot.

8. The method of claim 6 wherein each communication frame comprises at least one time division multiple access frame having a plurality of time slots, at least one of the plurality of time slots of a particular hop frame comprising the synchronization channel time slot, the step of determining the predetermined hopping pattern further comprises:

(a) acquiring a frame number according to a step selected from the group consisting of:

(i) determining the frame number from the synchronization channel time slot data bits; and

(ii) determining a reduced frame number from a plurality of synchronization channel time slot data bits, the reduced frame number identifying a co-set of communication frames including a single synchronization channel time slot within a predetermined communication frame of the co-set of communication frames, and subsequently determining the frame number from the determined reduced frame number and the predetermined communication frame of the co-set of communication frames; and

(b) deriving the predetermined hopping pattern from the acquired frame number according to a step selected from the group consisting of:

(i) using the acquired frame number to retrieve the particular hopping pattern from a lookup table of hopping patterns; and

(ii) deriving the particular hopping pattern as a function of the acquired frame number.

9. The method of claim 6 further comprising at least one of the following steps from the group consisting of:

(a) wherein each of the plurality of communication frames comprises a plurality of time slots, at least one of the plurality of time slots of a particular communication frame of the plurality of communication frames comprising the synchronization channel time slot, and at least another of the plurality of time slots of the particular communication frame comprising a frequency correction channel time slot, the frequency correction channel time slot information indicating that the synchronization channel time slot is located within an earlier transmitted time slot within the particular communication frame, the step of detecting the synchronization channel time slot comprises:

(i) concurrently storing information from a plurality of time slots including the frequency correction channel time slot and the synchronization channel time slot; and

(ii) retrieving synchronization channel time slot information from the stored particular earlier transmitted time slot and determining the predetermined hopping pattern therefrom;

(b) wherein each of the plurality of communication frames comprises a plurality of time slots, at least one of the plurality of time slots of a particular communication frame of the plurality of communication frames comprising the synchronization channel time slot, and at least another of the plurality of time slots of the particular communication frame comprising a frequency correction channel time slot, the frequency correction channel time slot information indicating that the synchronization channel time slot is located within a later transmitted time slot within the particular communication frame, the step of detecting the synchronization channel time slot comprises the step of acquiring synchronization channel time slot information

from the particular later transmitted time slot and determining the predetermined hopping pattern therefrom;

(c) wherein the step of detecting the synchronization channel time slot comprises iteratively and sequentially setting a local oscillator to a frequency until the synchronization channel time slot is detected;

(d) the step of detecting a control channel by hopping the frequency of a receiver according to the predetermined hopping pattern, wherein the synchronization channel time slot comprises data bits from which a plurality of predetermined hopping patterns can be derived, the step of hopping comprises

(i) hopping a frequency of a receiver according to a first and a second predetermined hopping pattern such that a first and a second control channel may be detected, respectively; and

(ii) selecting one of the first and the second predetermined hopping pattern to continue hopping the frequency of the receiver based on a comparison of a measured signal quality of the first and the second detected control channel.

10. A method for providing a hopping pattern to a communication unit for use in a frequency hopping communication system, comprising:

(a) detecting a global position satellite information; and

(b) acquiring a predetermined hopping pattern by utilizing the detected global position satellite information, the predetermined hopping pattern specifying the sequence over which a plurality of communication frames are hopped over a plurality of carrier frequencies.

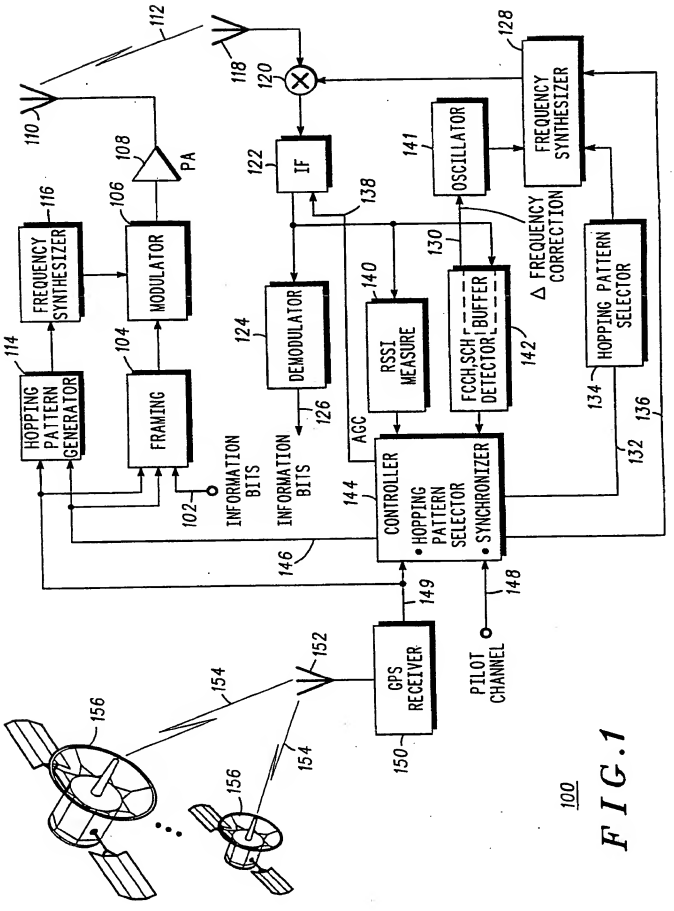

FIG. 1

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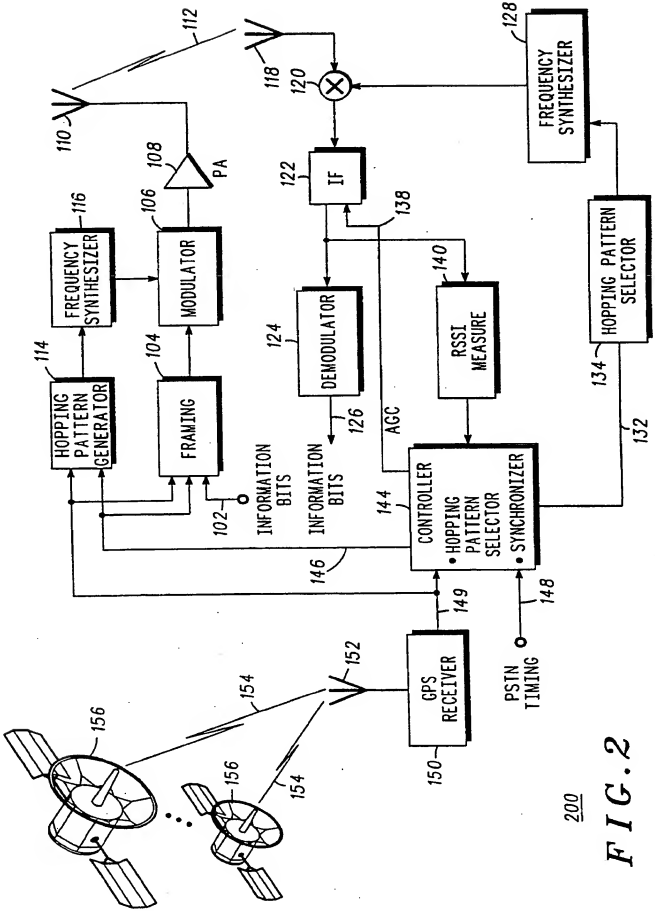

FIG. 2

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FIG.3

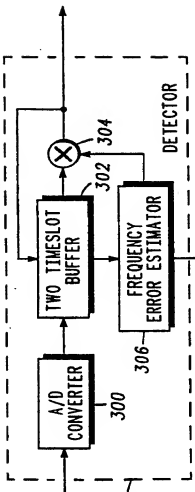


FIG.4

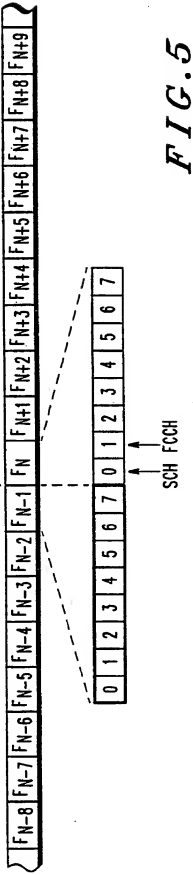
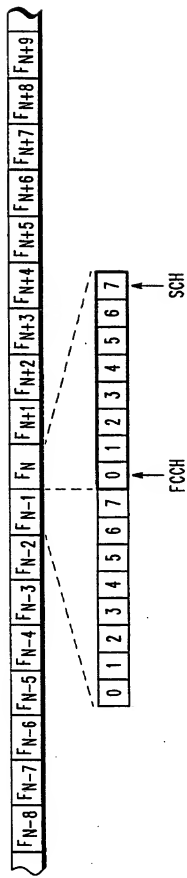


FIG.5



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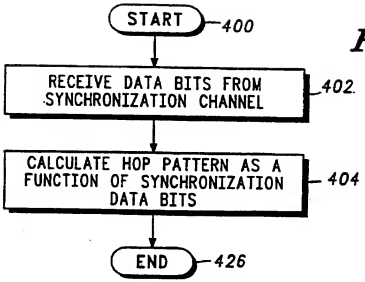

FIG. 6

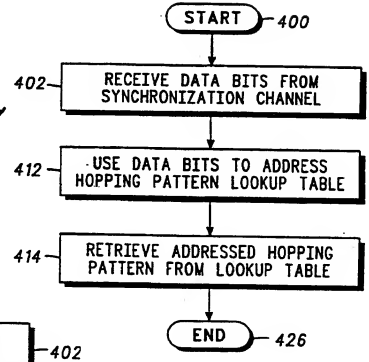

FIG. 7

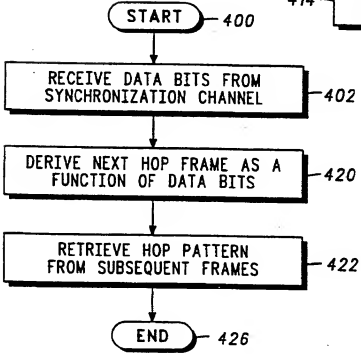

FIG. 8

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FIG.9

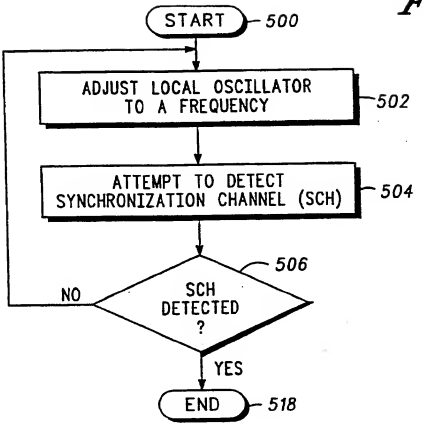
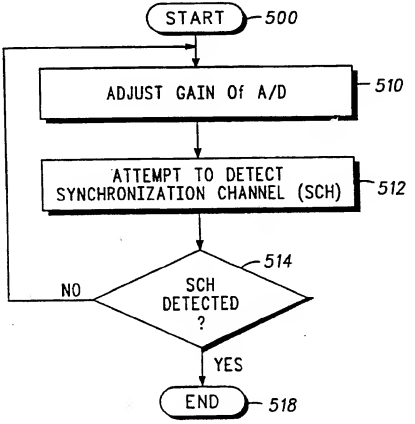


FIG.10



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/07565

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04L 27/30
US CL :375/1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/1
380/34; 342/352, 357

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,807,248 (PYATT ET AL) 21 FEBRUARY 1989.	1-10
A	US, A, 5,079,768 (FLAMMER) 07 JANUARY 1992.	1-10
A	US, A, 5,097,485 (O'CONNOR ET AL) 17 MARCH 1992.	1-10
A	US, A, 5,123,029 (BANTZ ET AL) 16 JUNE 1992.	1-10
A	US, A, 5,130,987 (FLAMMER) 14 JULY 1992.	1-10
A	US, A, 5,177,765 (HOLLAND ET AL) 05 JANUARY 1993.	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 19 AUGUST 1994	Date of mailing of the international search report SEP 02 1994
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer BENARR EARL GREGORY Telephone No. (703) 308-0479

Form PCT/ISA/210 (second sheet)(July 1992)*

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